PRINT HEAD DRIVE

BACKGROUND

[0001] The present exemplary embodiment relates generally to an apparatus and a method for driving a print head in a printing system and, more specifically, to a drive system which allows the print head to maintain alignment with a transfer surface with little or no adjustment during regular use. However, it is to be appreciated that the present exemplary embodiment is also amenable to other like applications.

[0002] Ink jet printing involves the delivery of droplets of ink from nozzles in a print head to form an image. The image is made up of a grid-like pattern of potential drop locations, commonly referred to as pixels. The resolution of the image is expressed by the number of ink drops or dots per inch (dpi), with common resolutions being 300 and 600 dpi.

[0003] Ink jet printing systems commonly utilize either direct printing or offset printing architecture. In a typical direct printing system, ink is ejected from jets in the print head directly onto a final receiving medium, such as a sheet of paper. In an offset printing system, the print head jets the ink onto an intermediate transfer surface, such as a liquid layer on a drum. The final receiving medium is then brought into contact with the intermediate transfer surface and the ink image is transferred and fused or fixed to the medium. In some direct and offset printing systems, the print head moves relative to the final receiving medium or the intermediate transfer surface in two dimensions as the print head jets or orifices are fired. Typically, the print head is translated along an X-axis while the final receiving medium/intermediate transfer surface is moved along a Y-axis. In this manner, the print head "scans" over the print medium and forms a dot-matrix image by selectively depositing ink drops at specific locations on the medium.

[0004] Printers of the offset type may employ a single print head which delivers ink droplets to a drum. The drum rotates multiple times during the formation of an image. Typically, the print head includes a jetstack or plate which defines multiple jets configured in a linear array to print a set of scan lines on the intermediate transfer surface with each drum rotation. With each rotation, X-axis translation of

the print head causes the jets to be offset by one or more pixels, enabling the printer to create a solid fill image, continuous line, or the like, depending on the particular combinations of jets fired.

[0005] Precise placement of the scan lines is important to meet image resolution requirements and to avoid producing undesired printing artifacts, such as banding and streaking. Accordingly, the X-axis (print head translation) and Y-axis (drum rotation) motions are carefully coordinated with the firing of the jets to ensure proper scan line placement.

[0006] As the size of the desired image increases, the X-axis movement/head translation and/or Y-axis motion requirements become greater. One technique for printing larger-format images is disclosed in U.S. Pat. No. 5,734,393 for INTERLEAVED INTERLACED IMAGING, assigned to the assignee of the present patent. This application discloses a method for interleaving or stitching together multiple image portions to form a larger composite image. Each of the image portions is deposited with a separate X-axis translation of the print head. After the deposition of each image portion, the print head is moved without firing the jets to the start position for the next image portion. Adjacent image portions overlap and are interleaved at a seam to form the composite image. In this image deposition method, the relative position of each image portion is carefully controlled to avoid visible artifacts at the seam joining adjacent image portions.

[0007] Prior art ink jet printers have utilized various mechanisms to impart X-axis movement to a print head. An exemplary patent directed to an X-axis positioning mechanism is U.S. Pat. No. 5,488,396 for PRINTER PRINT HEAD POSITIONING APPARATUS AND METHOD (the '396 patent), assigned to the assignee of the present application. This patent discloses a motion mechanism comprising a stepper motor that is coupled by a metal band to a lever arm. Rotation of the lever arm imparts lateral X-axis motion to a positioning shaft that is attached to the print head. This mechanism translates each step of the stepper motor into one pixel of lateral X-axis movement of the print head. The amount of X-axis translation per step of the stepper motor is adjustable by an eccentrically mounted ball that is positionable on the lever arm.

[0008] An exemplary patent directed to an X-axis drive mechanism is U.S. Patent No. 6,244,686 (the '686 patent) entitled PRINT HEAD DRIVE MECHANISM, and

assigned to the assignee of the present application. The '686 patent discloses a motor coupled to a lead screw by gears. While the drive mechanism of the '396 patent provides highly accurate and repeatable movement of a print head, it is nevertheless subject to minor displacement errors arising from such factors as imbalances in stepper motor phase and thermal expansion of various components under changing operating temperatures. The motor is connected with the positioning shaft by multiple gears, each gear contributing to the difficulty in maintaining tolerances. When the positioning shaft is not axially aligned with the print head, this can lead to stresses in the drive system, leading to shortened expected lifetime. Additionally, the stresses developed may cause the print head to become misaligned with the transfer drum. These misalignments tend to be of less significance when the jetstack height is relatively small.

[0009] Periodically, such offset printers are recalibrated to compensate for minor displacements in the print head or drum. In ink jet printers with a short jet array height, e.g., of about 5 mm, or less, the most sensitive alignment parameter has generally been the distance between the jetstack and the drum. Alignment is accomplished by adjustment of the print head and print engine, typically by using adjustment screws. The print head is thus fixed at a preselected spaced distance from the drum, leaving a gap between the drum and the jetstack. However, the adjustment screws do not control movement in all directions so there remains a possibility for mismatches in alignment to occur.

[0010] The present exemplary embodiment contemplates a new and improved print head drive system and method which overcome the above-referenced problems and others.

BRIEF DESCRIPTION

[0011] In accordance with one aspect of the present exemplary embodiment, a drive system for driving a driven member is provided. The drive system includes a motor and a pivotable linkage which allows relative pivoting between the driven member and the drive system. The pivotable linkage is operatively connected with the motor for advancing the driven member.

[0012] The advantages and benefits of the present exemplary embodiment will become apparent to those of ordinary skill in the art upon reading and understanding the following detailed description of the preferred embodiments.

[0013] Still further advantages and benefits of the present exemplary embodiment will become apparent to those of ordinary skill in the art upon reading and understanding the following detailed description of the preferred embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The exemplary embodiment may take form in various components and arrangements of components, and in various steps and arrangements of steps. The drawings are only for purposes of illustrating preferred embodiments and are not to be construed as limiting the exemplary embodiment.

[0015] FIGURE 1 is a simplified block diagram of an exemplary offset ink-jet printing apparatus that utilizes the alignment system of the present invention;

[0016] FIGURE 2 is a top plan view of a drum assembly and print head of the printing apparatus of FIGURE1;

[0017] FIGURE 3 is a perspective view, partially cut away of the drum assembly and print head of FIGURE 2;

[0018] FIGURE 4 is an enlarged perspective view of the print head of FIGURE 2 and a print head drive mechanism;

[0019] FIGURE 5 is an enlarged perspective view of the print head of FIGURE 4;

[0020] FIGURE 6 is a greatly enlarged perspective view of a portion of the print head and drum assembly of FIGURE 3, showing a point of contact between the print head and drum assembly;

[0021] FIGURE 7 is a schematic view of a linkage between the drum and print head of FIGURE 2;

[0022] FIGURE 8 is a greatly enlarged perspective view of a left hand end of the print head of FIGURE 2 with a biasing assembly;

[0023] . FIGURE 9 is a sectional view of the left hand end of the print head of and part of the biasing assembly of FIGURE 8;

[0024] FIGURE 10 is an enlarged perspective view of the print head drive mechanism of FIGURE 4;

[0025] FIGURE 11 is a side sectional view of the of the print head drive mechanism of FIGURE 10;

[0026] FIGURE 12 is an enlarged side view of the lead screw and nut portion of the drive member of FIGURE 11;

[0027] FIGURE 13 is an enlarged perspective view of the right hand stub shaft of the print head and a guide rib of the print head drive mechanism of FIGURE 10;

[0028] FIGURE 14 is an enlarged perspective view of a cone and nut assembly of FIGURE 11 engaging the guide rib of FIGURE 13;

[0029] FIGURE 15 is an enlarged perspective view of the print head drive mechanism of FIGURE 11 showing movement directions of the cone and nut assembly; and

[0030] FIGURE 16 is a perspective view of the drum, chassis, and right hand print head bearing of the printing apparatus of FIGURE 1.

DETAILED DESCRIPTION

[0031] While the present invention will hereinafter be described in connection with its preferred embodiments and methods of use, it will be understood that it is not intended to limit the invention to these embodiments and method of use. On the contrary, the following description is intended to cover all alternatives, modifications, and equivalents, as may be included within the spirit and scope of the invention as defined by the appended claims.

[0032] With reference to FIGURE 1, an imaging system **10** is shown. The exemplary imaging system **10** is a printing apparatus which utilizes a single print head for performing an offset or indirect ink jet deposition method. Examples of this type of offset ink-jet printing apparatus is disclosed in U.S. Patent No. 5,389,958 (the '958 patent) entitled IMAGING PROCESS, and U.S. Patent No. 6,213,580 for an APPARATUS AND METHOD FOR ALIGNING PRINT HEADS (the '580 patent), which are assigned to the assignee of the present application. The '580 and '958 patents are hereby specifically incorporated by reference in pertinent part. It will be appreciated, however, that the present apparatus and method may also be employed with various other ink-jet printing devices which utilize different architectures, including multiple print head printing devices.

[0033] With continued reference to FIGURE 1, the printing apparatus **10** receives imaging data from a data source **12**. A printer driver **14** within the printer **10** processes the imaging data and controls the operation of a print engine **16**. The printer driver **14** feeds formatted imaging data to a print head **18** of the print engine **16** and controls the movement of the print head by sending control data to a motor controller **19** that activates an X-axis drive mechanism **20**. The printer driver **14** also controls the rotation of a transfer drum **26** by providing control data to a motor controller **27** that activates a drum motor **28**.

[0034] With reference also to FIGURE 2, the print head **18** of the print engine **16** includes a jetstack **32** in the form of a perforated plate that extends parallel to the transfer drum **26**. In operation, the print head **18** is moved parallel to the transfer drum **26** along an X-axis as the drum **26** is rotated and print head jets or nozzles **33** (FIG. 3) in the form of orifices in the jetstack **32** are fired. Rotation of the drum **26** creates motion in a Y-axis direction relative to the print head **18**, as indicated by arrow Y (FIG. 3). Liquid or molten ink is ejected from the print head nozzles **33** onto an intermediate transfer surface **34** (FIG. 2), which forms an outer cylindrical surface of the drum **26**.

[0035] As shown in FIGURE 3, which shows a perspective view with the drum omitted for clarity, the drum **26** is mounted for rotation on a shaft **36** (shown in phantom). The shaft **36** and drum **26** are the moving parts of a drum assembly **38**, the stationary parts of which will be described in greater detail below. The shaft **36** and associated drum **26** are rotated in the direction of action arrow **E**. In this manner, an ink image is deposited on an intermediate transfer layer (not shown). The intermediate transfer layer can be a liquid layer that is applied to the drum surface **34** with an applicator assembly (not shown), and may include, for example, water, fluorinated oils, surfactants, glycols, mineral oils, silicone oils, functional oils, and combinations thereof.

[0036] In one embodiment, the ink utilized in the printer **10** is initially in solid form and is then changed to a molten state by the application of heat energy. The molten ink is stored in a reservoir **40**, mounted to the print head, and is delivered to the jets **33**. The intermediate transfer surface **34** is maintained at a preselected temperature by a drum heater (not shown). On the intermediate transfer surface, the ink cools and partially solidifies to a malleable state.

[0037] One rotation of the transfer drum **26** and a simultaneous translation of the print head **18** along the X-axis while firing the ink jets **33** results in the deposition of an angled scan line on the intermediate transfer layer of the drum **26**. It will be appreciated that one scan line has an approximate width of one pixel (one pixel width). In 300 dots per inch (dpi) (about 118 dots per cm) printing, for example, one pixel has a width of approximately 0.085 mm. Thus, the width of one 300 dpi scan line equals approximately 0.085 mm.

[0038] With reference also to FIGURE 4, an alignment system **50** maintains alignment of the print head jetstack **32**, relative to the transfer surface **34** of the drum **26,** to minimize unwanted relative movement between the jetstack and the drum during printing. The alignment system **50** thus minimizes unwanted movement (as opposed to the desired X-axis translation of the print head and rotation of the drum), which can result in undesired printing artifacts, such as banding and streaking.

[0039] As illustrated in FIGURE 3, an object which is free to move is space has six degrees of freedom, illustrated by perpendicular axes X, Y, Z and rotational axes R_x, R_y, R_z. To constrain the object against movement, all six degrees of freedom need to be controlled. The present alignment system **50** acts to constrain the jetstack **32** against unwanted movement in all six degrees of freedom, thereby facilitating the use of a larger jet array height **j** (the vertical height between upper and lowermost jets **33**) than has been possible with prior systems. The alignment system **50** uses a linkage of components, which will be described in greater detail below. The linkage provides three contact points to define a plane and a fourth point to constrain the print head against rotation. In this way, the print head, and hence the jetstack, are accurately positioned without the need for recalibration once the printer leaves the factory.

[0040] Print quality has been found to be sensitive to three alignment tolerance parameters, as follows:

1. The print head-to-drum distance (HTD), which is the distance across the gap between the jetstack **32** and the drum **26** in the Z-axis in the region of the jets (FIGURE 2, not to scale). If there is a difference in HTD between left and right sides of the printer, this is known as HTD

skew or yaw. In conventional printers, this distance is measured and is an important part of a recalibration process.

2. The head height (HH) is the distance between the centerline C of the jet array and the drum midline M in the Y-axis (FIGURE 3, not to scale). Since the drum is cylindrical, relative movement in the Y-axis or rotation about the Z-axis (referred to as pitch) also adds to the head height. This combination of head height variation and pitch is referred to as hilt.

3. The head roll is the difference in head height between the right and left sides of the print head (roll about the Z-axis).

[0041] The alignment system **50** allows each of these alignment parameters to be controlled to maintain print quality, without the need for recalibration. It will be appreciated that the terms "left" and "right" refer to the arrangement of the print head **18** and drum **26** illustrated in FIGURES 2 and 3.

[0042] With reference to FIGURES 4 and 5, which show one embodiment of a print head **18** with the jetstack removed for clarity, the print head **18** is mounted to left and right stub shafts or journal pins **60**, **62** by left and right mounting towers **64, 66**, respectively, at opposed ends of the print head. As explained in more detail below, the print head drive mechanism **20** translates the right stub shaft **62** along the X-axis and thus the coupled print head **18** moves in a direction parallel to the X-axis. It will be appreciated that the drive mechanism **20** could, alternatively, translate the left stub shaft **60**, if its position were changed. The X-axis is defined as being collinear with an axis through the stub shafts **60**, **62** (FIG. 5).

[0043] An upper end **68** of the print head **18** can be biased about rotational axis $\mathbf{R_x}$ in a direction towards the drum **26**, by a biasing member or members, such as one or more head tilt springs **70**. A single head tilt spring **70** is illustrated in FIGURE 2, between left and right mounting towers **64, 66**. The print head **18** makes contact with the drum assembly **38** at first and second contact points **74**, **76**, adjacent left and right sides of the print head respectively. The contact points **74**, **76** are defined by first and second contacting members **78, 80** (FIG. 4), in the form of hard stops, carried by the print head **18**, and corresponding first and second receiving members **82, 84** in the form of buttons, carried by the drum (FIG. 3). It will be appreciated that in FIGURE 3, part of the drum assembly is shown cut away, so that the buttons **82,**

84 are visible. Additionally, or alternatively, the center of gravity of the reservoir **40** and print head **18**, being forward (closer to the drum) than the shafts **60, 62**, helps to keep the hard stops in contact with the buttons.

[0044] As shown in FIGURE 5, the print head **18** includes a front reservoir plate **90,** formed from a rigid material, such as aluminum, which is integrally formed with or otherwise rigidly mounted to the left and right mounting towers **64, 66**. The front reservoir plate **90** includes generally cylindrical extension members **92, 94**, which extend from left and right sides of the reservoir plate **90**, respectively, parallel with the X-axis. The extension members are integrally formed with or otherwise rigidly connected with the front reservoir plate **90**. Cylindrical blocks **96, 98**, formed from stainless steel or other hardened material, are mounted within the extension members **92, 94**, respectively. A front face **100, 102** of each of the blocks **96, 98** defines a generally planar contacting surface of the respective hard stop **78, 80**.

[0045] While in the illustrated embodiment, the hard stops **78, 80** are carried by the reservoir plate **90**, in an alternative embodiment, the hard stops are carried by the jetstack **32**. In yet another embodiment, the positions of the hard tops and buttons are reversed, with the hard stops being carried by the drum assembly and the buttons being carried by the print head.

[0046] As illustrated in FIGURE 3, which shows part of the drum assembly **38** cut away for clarity, the buttons **82, 84** are mounted to a stationary part of the drum assembly, by generally cylindrical labyrinth seals **110, 112**. The buttons can be formed from a resilient plastic or other suitable material which undergoes little or no deformation on contact with the hard stops **78, 80** and which provides a low friction contact with the steel material of the hard stops. The buttons **82, 84** may each have a convex, spherical tip, which provides a single point of contact with the respective hard stop **78, 80**, while allowing for any misalignment between the button and the hard stop. As the print head **18** translates during printing, the hard stops **78, 80** make sliding contact with the buttons **82, 84**, over the length of travel of the print head. Thus, for contact to be maintained throughout the printing operation, the X-directional width of the contacting surfaces **100, 102** of each of the hard stops is greater than a length of travel of the print head during translation.

[0047] As shown in FIGURE 6, which shows the left hand button **82**, the buttons are mounted within suitably positioned sockets **113** in peripheral portions **110, 112**

of left and right stationary frames **114, 116.** These frames **114, 116**, also referred to as "labyrinth seals" carry the bearings for the drum shaft **36** (illustrated in phantom in FIGURE 3) via a central aperture **118** formed therein. The sockets **113** extend into the frames **114, 116** to which the buttons are rigidly mounted. The frames or "labyrinth seals" as implemented are formed from cast aluminum. Alternate materials are considered. The head tilt spring **70** biases the upper end of the print head **18** such that the hard stops **78, 80** remain in contact with the buttons **82, 84**, as shown in FIGURE 6.

[0048] As illustrated schematically in FIGURE 7, the drum assembly **38** is rigidly mounted to a chassis **120** of the printer. Specifically, the drum labyrinth seals **114, 116** are mounted by bolts, screws, or the like to the chassis **120**. The chassis **120** may be formed from metal, hard plastic, or other relatively rigid material. The chassis **120** forms a part of a three part linkage **122** between the drum labyrinth seals **114, 116** (and hence the buttons) and the hard stops, via the print head drive mechanism **20** and right stub shaft **62**, which constrains the movement of the print head. The linkage **122** includes a first linkage portion **122A,** which links the buttons **82, 84** to the labyrinth seals **114, 116**, a second linkage portion **122B**, which comprises the chassis **120** and links the labyrinth seals with the print head drive mechanism **20**, and a third portion **122C**, which links the print head drive mechanism **20** with the hard stops **78, 80**. In this way, two contact points in a plane are defined at **74, 76** (FIG. 2), with a third contact point in the plane defined by the right side x-axis stub shaft **62**. The stub shaft **62** is constrained in the Y-axis and Z-axis, as will be explained in greater detail below.

[0049] With reference once more to FIGURE 4, the left stub shaft **60** is biased along the X- axis, in the direction of the print head drive mechanism **20**, by a biasing assembly **130**. The biasing assembly **130** includes a bias spring **132,** which in the illustrated embodiment, is aligned with the X-axis (i.e., coaxial with the stub shafts **60, 62**), as far as tolerances reasonably permit. This alignment of the bias spring **132** with the X-axis serves to minimize any unwanted rotation of the print head **18** away from the drum **24** about the axes $\mathbf{R_y}$ and $\mathbf{R_z}$. The bias spring **132** serves to provide a constant bias force on the print head drive mechanism **20**. The length of the bias spring **132** allows it to have a low spring rate and to provide a nearly

constant force across the range of imaging motion, which in one embodiment, is approximately 4 mm.

[0050] An end **134** of the bias spring **132** closest to the drive mechanism **20** is mounted to the chassis **120** via a flange **136**, thus fixing the position of the right hand end **134** of the biasing assembly **130**, relative to the linkage **122**.

[0051] As shown in FIGURE 8, a left hand end **140** of the bias spring **132**, furthest from the drive mechanism **20**, is mounted to a right hand end of a hook-shaped retaining member **144.** The hook-shaped retaining member **144** is configured to pass below a lower end of the left mounting tower **64** and engage a distal end of the left stub shaft **60**, thereby maintaining the axial alignment of the bias spring **132**. Specifically, as illustrated in FIGURE 9, the distal end of the left stub shaft **60** defines a concave socket **146** with its midpoint aligned with the X-axis. The hook **144** defines an inwardly extending protrusion **148**, which is seated in the socket **146**, allowing a small amount of relative movement between the hook and the stub shaft toward the z-axis and/or y-axis to compensate for any slight misalignment between the chassis and the stub shaft **60**. The hook **144** and protrusion **148** are removable from the socket **146** for repair or replacement of the print head **18**. The tension in the bias spring **132** in the X-axis direction maintains the X-axis alignment of the hook and the stub shaft **60**.

[0052] In an alternative embodiment, the left and right stub shafts form ends of a single shaft which connects the left and right towers **64, 66.** In this embodiment, the bias spring **132** can be wound around a portion of the shaft which extends between the towers to minimize misalignment with the X-axis.

[0053] A roll block **150** is carried by the left stub shaft **60.** The roll block defines a plurality of bearing faces **152**, four in the illustrated embodiment, and a generally axial bore **154**, which snugly receives the stub shaft **60** therethrough, and within which the stub shaft is free to rotate. One of the bearing faces **152** makes sliding contact with an upper flat surface **156** of a left hand X-axis bearing **158**, which is rigidly mounted to the chassis **120**. The weight of the print head **18** is sufficient to provide a downward force on the roll block **150** in the Y-axis direction, keeping the roll block **150** in contact with the left bearing **158**. The bore **154** may be asymmetrically positioned, relative to the X-axis, thus providing each face with a slightly different distance from the X-axis, which may vary, for example, by a few

micrometers (e.g., 50 μm). This allows slight variations in the alignment to be accommodated. The block **150** can be rotated, after the print head **18** has been installed in the printer, such that the face **152** which provides the best alignment in the Y-axis is in contact with the left bearing **158**. Specifically, the asymmetry of the bore **154** allows the left stub shaft **60** to be raised or lowered by selection of the side **152** of the roll block that is placed against the left bearing **158**. The flat surface **156** of the bearing allows the block to slide relative to the bearing, for right to left image motion, as well as front to back sliding (Z-direction), so that the print head to drum alignment system **50** is not overly constrained.

[0054] A force spring **162** is positioned on the stub shaft **60**, intermediate the roll block **150** and the left hand end of the hook **144**. The force spring **162** biases the block **150** against axial movement along the stub shaft **60**. The force provided by the force spring **162** is less than that provided by the bias spring **132.** During right to left X-axis translation of the print head **18**, the increasing tension in the bias spring **132** maintains X-axis alignment of the stub shaft **60** and the hook **144.** When the tension is reduced, as in translation of the print head in the left to right direction, the force spring **162** compensates for any tendency of the block to slip along the stub shaft in the right to left direction by providing a force which exceeds the friction force between the upper surface **156** of the left bearing **158** and the bearing face **152** of the block. In this way, contact is maintained between the right end of the roll block and the left mounting tower **64**. In doing so, it assures sliding between the roll block **150** and the left bearing **158**, rather than between the roll block and the left stub shaft **60**. This helps to maintain constant and predictable forces which assist in minimizing positioning errors.

[0055] With reference once more to FIGURE 4, and reference also to FIGURES 10 and 11, the print head drive mechanism **20** includes a drive motor **170**, such as a stepper motor, which is operatively connected with a lead screw **172**. In the illustrated embodiment, the drive motor **170** is directly coupled with a first end **174** of the lead screw **172**, without any intermediate eccentric gears, so that the motor and lead screw are aligned as close to the X-axis as reasonable tolerances permit. In this way, any tendency for the motor to impart non axial motion to the lead screw is minimized. Additionally, the direct coupling reduces the number of parts in the print head drive mechanism **20**, and the stacked tolerances which this can entail.

[0056] In one embodiment, the stepper motor **170** has about 200 steps per revolution and is driven to provide 128 microsteps per whole step. The lead screw can have a pitch of about 18.75 turns per inch (TPI). This provides an addressable resolution of about 0.053 μm.

[0057] In an alternative embodiment (not shown), a motor is coupled to a lead screw by gears as is disclosed, for example, in U.S. Patent No. 6,244,686 (the '686 patent), which is hereby specifically incorporated by reference in pertinent part.

[0058] With continued reference to FIGURES 10 and 11, the lead screw **172** carries drive member **180**, such as a nut and cone assembly, at a distal end **182** thereof. The nut and cone assembly **180** converts the rotational movement of the lead screw **172** into axial movement in the X-direction. Specifically, the assembly **180** includes an internally threaded nut portion **184,** within which the lead screw rotates. Threads **186** of the lead screw engage the internal threads **188** of the nut portion **184**. The nut portion **184** is constrained against rotational movement by a guide member or anti rotation device **190**, such as a guide rib, as illustrated in FIGURES 13 and 14. The guide rib **190** extends generally parallel with the X-axis and can be mounted to a portion of the chassis **120**. The nut portion **184** includes a lateral groove or slot **192** (FIG. 14), which receives the rib **190**. During axial translation of the print head, rotation of the lead screw **172** causes the nut and cone assembly **180** to advance, while the nut portion **184** slides along the rib **190**. The groove **192** maintains contact with one of the upper and lower horizontal surfaces **194, 196** of the rib during translation. In the illustrated embodiment, the groove **192** is slightly wider, in the Y-direction, than the rib **190**, such that there is a small amount of rotational play permitted between the groove and the rib. So that this limited amount of play does not affect the drum to print head alignment, the printing can be carried out only in one axial direction, which may be in the right to left direction. In this way, the groove **192** always engages the same face of the rib **192** during printing.

[0059] It will be appreciated that the locations of the groove and guide rib may be reversed, by placing the groove on the chassis and a rib on the nut and cone assembly. Other means for limiting rotation of the nut and cone assembly **180** are also contemplated.

[0060] With reference once more to FIGURE 11, the nut and cone assembly **180** further includes a cone portion **200**, which for ease of manufacture, may be formed separately from the nut portion **184** and welded or otherwise fixedly attached thereto at a right hand end of the cone portion by means of pins **202**. The cone portion **200** is generally conical in shape with a tip **204** at its distal end, which may be semispherical, as illustrated, although parabolic or elliptically curved tips are also contemplated. The tip **204** makes contact with the right stub shaft **62**. Specifically, the right stub shaft **62** defines a concave socket **206**, similar to socket **146** of the left stub shaft **60**. The midpoint of the socket **206** is aligned with the X-axis. The socket is sized to receive the tip **204** therein and allow relative pivoting between the stub shaft **62** and the cone portion **200**.

[0061] Although the lead screw **172** is nominally aligned with the X-axis, slight variations in alignment inevitably occur, either during assembly or in subsequent use of the printer. The flexible coupling created by the contacting of the right stub shaft **62** with the cone portion **200** allows these small variations to be accommodated by allowing the cone and nut assembly to pivot, relative to the right stub shaft. As will be appreciated, the bias spring **132** provides a biasing force in the general direction of the motor **170**, which maintains sufficient contact between the tip **204** and the journal socket **206** to avoid misalignment of the print head during printing.

[0062] The nut and cone assembly **180** accommodates any residual misalignment of the lead screw **172** with the print head **18** due to tolerances of the components. Additionally, the assembly **180** accommodates run out of the nut cone assembly (variations along the threaded portion of the nut cone assembly which engage different portions of the lead screw during translation) which cause changes in alignment during translation of the print head. To allow the nut and cone assembly **180** to gimbal at both ends, the threads **188** of the nut portion **184** have a slightly wider diameter than the diameter of the lead screw threads **186**, as illustrated in FIGURE 12. This allows the nut and cone assembly to have a small amount of play relative to the lead screw **172**. In this way, the nut and cone assembly **180** can pivot slightly in Y and/or Z directions, relative to the lead screw, to accommodate slight misalignment of the lead screw. Arrows A, B shown in FIGURE 15 illustrate how the cone tip **204** can move, relative to the lead screw **172**. For

example, if the lead screw is slightly lower than the X-axis, the tip **204** of the nut and cone assembly will pivot slightly upward, and the nut portion will move accordingly.

[0063] It will be appreciated that the nut and cone assembly could alternatively define a concave distal surface, similar to the socket **206** of the right stub shaft, which receives a convex surface on the right stub shaft, similar in shape to the tip **204** of the cone portion **200**, i.e., the positions of the two shapes are reversed.

[0064] The linkage provided by the nut and cone assembly **180** is important for several reasons. First, it allows the weight of the print head **18** to rotate the link until the right stub shaft **62** is seated in a right hand X-axis bearing **210** (FIG. 13). Without this, the normal force between the nut and cone assembly **180** and the print head, due to the bias spring **132**, and the resulting friction, could prevent seating of the stub shaft in the bearing **210**. Second, it accommodates misalignment between the lead screw **172** and the stub shaft socket **206**. This avoids undue pressure on the lead screw which may occur from a rigid connection. Third, the linkage accommodates misalignment due to lead screw radial run out.

[0065] Thus, unlike prior printer drives, the illustrated lead screw **172** is not rigidly coupled to the right stub shaft **62**. The flexible coupling **180** of the present stub shaft **62** to the lead screw accommodates any slight misalignment between the lead screw and the X-axis, as defined by the stub shafts **60. 62**. However, it is contemplated that a rigid coupling may alternatively be employed.

[0066] The force of the bias spring **132** reduces backlash in the print head drive mechanism **20** by compressing gaps between the stub shaft socket **206** and cone tip **204**, the nut portion **184** and the lead screw threads **186**, as well as augmenting the preload to a thrust bearing (not shown) of the motor **170**.

[0067] Since the lead screw **172** is not coupled to the stub shaft **62** for reverse movement in the X-axis, it acts as a pusher drive only. Specifically, the cone and nut assembly **184** only pushes the print head **18** in the driving direction (right to left in the illustrated embodiment). The bias of the spring **132** is thus the return force for print head movements opposite to the drive direction (left to right).

[0068] The right stub shaft **62** is constrained against unwanted movement in the X-axis and Y axis. In the X-direction, the print head drive mechanism **20** and the bias spring **132** control the alignment of the print head. In the Y-direction, the weight of the print head **18** holds the right stub shaft **62** in contact with the right bearing

210, illustrated in FIGURE 4. As shown in FIGURE 16, the bearing **210** is mounted to a portion of the chassis **120** (and hence connected with the linkage **122**). The right bearing **210** defines a curved upper surface **212** which is shaped to receive the stub shaft **62** therein. The curvature of the upper surface **212** can be slightly less than that of the stub shaft **62** such that the constraint provided by the bearing **210** is in the Z direction as well as the Y direction.

[0069] A keeper (not shown), mounted to a bearing housing **216** constrains the stub shaft **62** against gross upward movement, for example, during transportation of the printer, or when the printer is tipped out of its ordinary horizontal alignment.

[0070] The position of the bias spring **132**, coaxial with the stub shafts **60, 62**, minimizes rotational motions induced in the print head **18**. This allows the forward center of gravity of the print head and reservoir **40**, along with the head tilt spring(s) **70** to cause rotation of the head about the right stub shaft **62** and sliding of the roll block **150** against the left bearing **158** until contact between both left and right labyrinth seal buttons **82, 84** and hard stops **78, 80** is made, thus achieving proper head alignment.

[0071] Features of the print head **18** and the drum assembly **38** define datums that fully constrain the position of the print head without over constraining it. The six degrees of freedom for the print head body are controlled as follows: The first two degrees of freedom are constrained in that two points of contact are defined by the buttons **82, 84** and the hard stops **78, 80** on the left and right sides of the print head, each point provides a single axis of constraint in the Z axis only. The next three degrees of freedom are constrained in that a third point, defined by the position of the right stub shaft **62**, is constrained in the Z and Y axis by the right bearing **210** and in the X axis by the X-axis nut/cone and bias spring **132**. The final degree of freedom is constrained in that a fourth point is created by the left bearing **60**, which is constrained in the Y-axis only, it prevents rotation of the print head about the print head Z-axis.

[0072] Tight tolerances between the drum **26** and the labyrinth seal buttons **82, 84** are attained by post machining the buttons, relative to the sockets **113**. The diameter of the drum transfer surface **34** is also machined with tight tolerances. The tolerance between the drum labyrinth seals **114, 116** and the X-axis bearings **158, 210** of the print head is controlled by side frames **220** of the chassis, only one of

which is illustrated in FIGURE 16. In practice, the most difficult tolerance to control can be the parallelism of each of the chassis side frames. This parallelism only affects roll, which is compensated for by selecting an appropriate orientation of the roll adjustment block **150**, as described above.

[0073] With reference now to FIGURES 3 and 4, tight tolerances are created between the jetstack **32**, the hard stops **78, 80**, and the x-axis stub shafts **60, 62**. This is achieved by placing alignment features on the jetstack **32** and on the front reservoir plate **90** of the print head. In particular, the front reservoir plate **90** includes several alignment pins **230** (three in the illustrated embodiment of FIGURE 4), which extend forwardly and are received through corresponding holes **232, 234** in the jetstack (FIG. 3). At least one of the holes **232** is oriented with its major dimension in a generally horizontal direction, while at least another of the holes **234** is oriented with its major dimension in a generally vertical direction. In both cases, the minor dimension of the hole is selected such that the respective pin **230** fits snugly in the hole, with a minimum of play.

[0074] The front reservoir plate **90** further includes a plurality of posts **240** (FIG. 5). The posts each have a distal end surface, machined flat, which engages a rear surface **242** of the jetstack, as illustrated in FIGURE 2. To lower the tolerance that the thickness of the jetstack **32** contributes to head-to-drum distance, notches **243** may be formed in the jetstack around the posts **240** such that only selected ones of the posts are used. As shown in FIGURE 3, a retaining plate or drip plate **244**, in cooperation with clips **246**, holds the jets stack **32** firmly against the posts. Specifically, the retaining plate **244** includes a plurality of holes **248** for receiving studs **250** therethrough which screw into corresponding bosses **252** in the front reservoir plate **90** (FIG. 4). The posts **240** and bosses **252** serve as spacers between the jetstack **32** and the reservoir plate **90**. The clips **246** clamp an upper end of the jetstack against the reservoir plate **90**.

[0075] In one embodiment, an assembly **254** comprising the reservoir plate **90** (including the alignment pins **230**, bosses **252**, posts **240**, extension members, and left and right hard stops), and left and right stub shafts **60**, **62**, and left and right mounting towers **64, 66**, is integrally formed of one piece, such as by molding, followed by any machining appropriate. Alternatively, the stub shafts **60, 62** may be separately formed and then rigidly attached to the towers **64, 66**.

[0076] The alignment system **50** thus described maintains alignment of the print head **18** with the drum **26** throughout the printer lifetime, even where slight changes due to wear, warping, or thermal expansion/contraction of the chassis occur.

[0077] The three key alignment tolerance parameters which affect print quality are all taken into consideration by the alignment system **50**. Head-to-Drum distance is controlled by the interface between the hard stops **78, 80** and the jetstack **32** and between the drum **26** and the labyrinth seal buttons **82, 84**. The gap across the entire length of the jetstack between the right and left hard stops is thus maintained within tight tolerances, minimizing HTD skew or yaw. The alignment system also provides stability of the tolerance during shipping and handling. Head height is controlled with the X-axis stub shaft interface by maintaining a tight tolerance between the jet array and the print head X-axis and between the drum labyrinth seals **114, 116** and the X-axis bearings **158, 210**. The left side X-axis stub shaft **60** is free to move fore and aft. Pitch and Height, or Hilt, are thus minimized.

[0078] Head Roll is the only alignment parameter that is adjusted. This is accomplished using the roll block **150** with the eccentric bore **154**. Typically, once the block adjustment has been made at the factory, no further adjustments of the block are necessary during the lifetime of the printer.

[0079] The alignment system enables the print head **18** to be accurately aligned with the drum **26** which avoids the need for subsequent print head adjustments, reduces the extent of engine adjustments, and minimizes the risk of print head damage to the drum.

[0080] The exemplary drive system **20** is formed with fewer components, reducing the effects of stacked tolerances. The exemplary drive system also allows movement of the print head **18** relative to the drive system in order for the print head to maintain alignment with the transfer surface **34**.

[0081] While the embodiments have been described with particular reference to printers, it will be appreciated that there are other applications for the alignment system described, including, but not limited to other imaging devices, such as fax machines, copiers, scanners, and the like.

[0082] Without intending to limit the scope of the invention, the following example demonstrates the accuracy of the positioning system.

EXAMPLE

[0083] The performance of a printer formed as described above and illustrated in the drawings was evaluated by measurement of position versus time using a laser interferometer. Harmonic excursion errors were less than ± 2.5 µm. Full scale motion errors were measured by scanning the printed images made by a population of 120 printers. Across the 4 mm travel range, the drive yielded errors of less than ±10µm (i.e., ± 3 standard deviations). Hysteresis errors, also measured with laser interferometer, were less than 15µm. Hysteresis error is dominated by the clearance between the nut guide slot **192** and the chassis guide rib **190**. Because the image process is unidirectional, the magnitude of this error has not been a concern.

[0084] The exemplary embodiment has been described with reference to the preferred embodiments. Obviously, modifications and alterations will occur to others upon reading and understanding the preceding detailed description. It is intended that the exemplary embodiment be construed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof. The recited order of processing elements or sequences, or the use of numbers, letters, or other designations therefore, is not intended to limit the claimed process to any order except as specified in the claim itself.